

# Retinex Image Enhancement: Applications to Medical Images

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## Retinex Image Enhancement—General Information

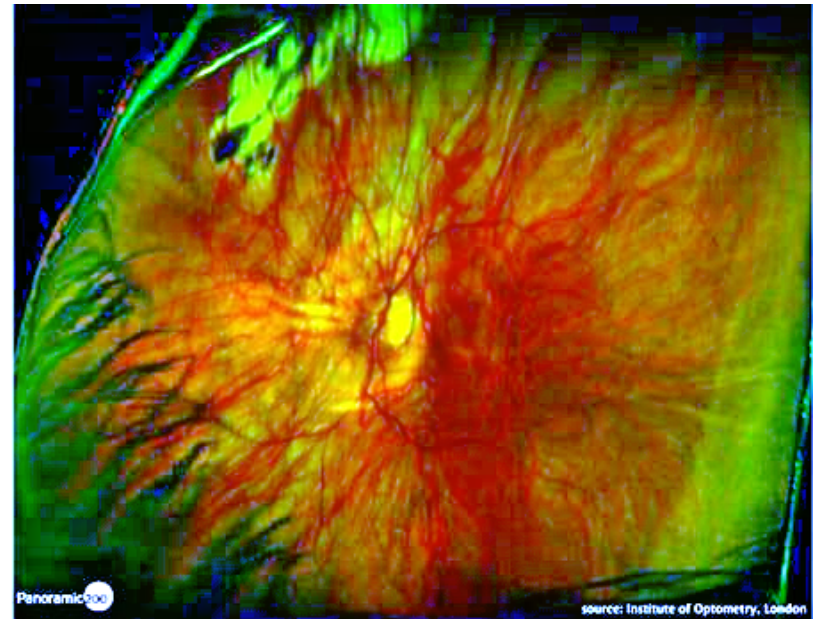
- The Multiscale Retinex with Color Restoration—Retinex for short—is a general purpose image enhancement algorithm.
- It is patented:
  - US patent #5,991,456, and two others pending.
  - Australia patent #713706 (International #US97/07996)
  - Pending in several other European and Asian countries.
- TruView Imaging Company, Hampton, Virginia holds the exclusive licensing rights.

## Retinex Image Enhancement—Potential Applications

- Any medical imaging application where automatic contrast enhancement and sharpening is needed. Potential areas of impact may include
  - Digital X-ray
  - Digital Mammography
  - CT scans
  - MRI
- Telemedicine applications where bandwidth between patient and doctor poses a potential bottleneck. The Retinex compacts the high input dynamic range, potentially reducing the bandwidth requirement.

## Retinex Image Enhancement—Background

- The Retinex provides automatic
  - Dynamic range compression: i.e., the ability to represent large input dynamic range into relatively small output dynamic range.

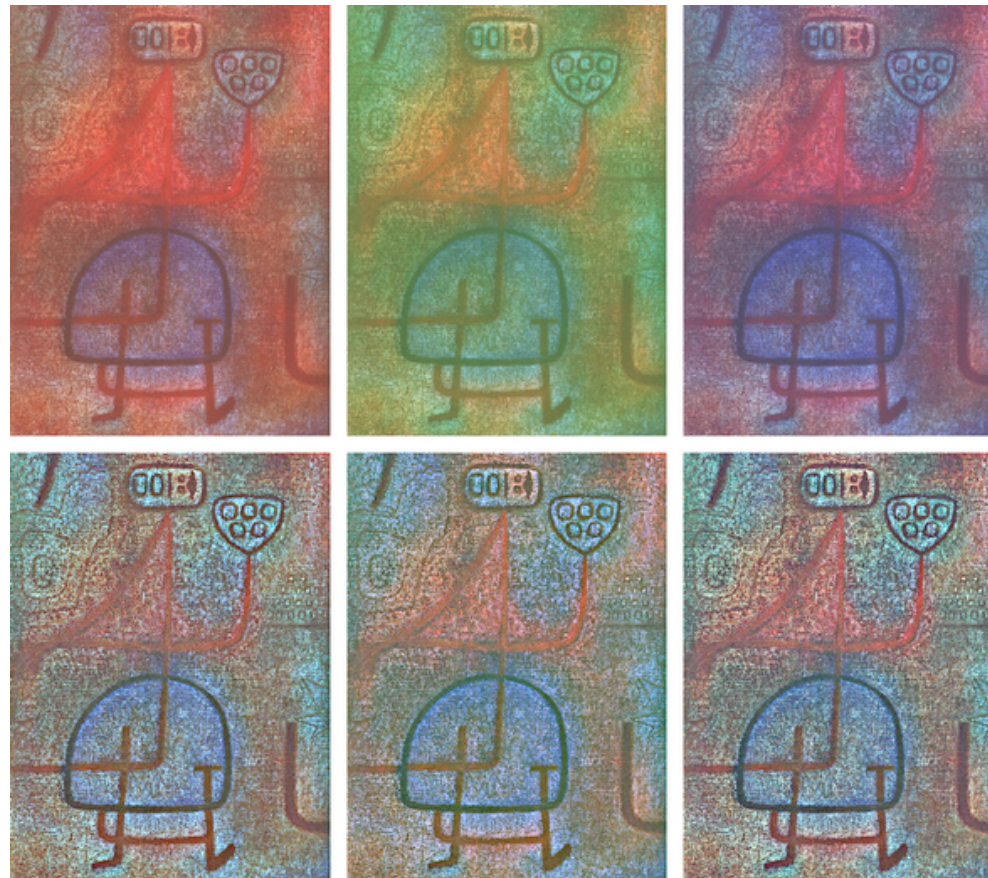


- Sharpening: i.e., compensation for the blurring introduced into the image by the image formation process. This allows fine details to be seen more easily than before.





- Color constancy: i.e., the ability to remove the effects of the illumination from the output. This allows consistency of output as the illumination changes.



## Retinex Image Enhancement—Technical

- The Retinex takes an input digital image  $I$  and produces an output image  $R$  on a pixel by pixel basis in the following manner:

$$\begin{aligned} R(x, y) &= \log (I(x, y)) - \log (I(x, y) * M(x, y)) \\ &= \log \left( \frac{I(x, y)}{I(x, y) * M(x, y)} \right) \end{aligned}$$

where  $M(x, y) = \exp ((x^2 + y^2)/\sigma^2)$ ,  $\sigma$  is a constant which controls the extent of  $M$ , and  $*$  represents spatial convolution.

- This non-linear transform has some interesting properties:
  - It mimics the spatial aspect of color perception by setting the output value as a function of the center (numerator in the equation) and its surround (the denominator in the equation).
  - The ratioing operation in conjunction with the log function inherently perform dynamic range compression.
  - The output is independent of the illumination source.



- The input image can be written as the product of two components:  $\rho(x, y)$  the reflectance component which represents the light reflected from all the objects in the scene being imaged, and  $i(x, y)$  which represents the illumination component. That is,

$$I(x, y) = i(x, y)\rho(x, y).$$

- Since the illumination component varies very slowly across the scene,  $I(x, y) \approx I_o\rho(x, y)$ , and

$$\begin{aligned} R(x, y) &= \log \left( \frac{I_o\rho(x, y)}{I_o\rho(x, y) * M(x, y)} \right) \\ &= \log \left( \frac{\rho(x, y)}{\rho(x, y) * M(x, y)} \right) \end{aligned}$$

- By performing the same operation on each color channel, the output color image can be written as

$$R_i(x, y) = \log \left( \frac{I_i(x, y)}{I_i(x, y) * M(x, y)} \right) \quad i \in \{R, G, B\}$$

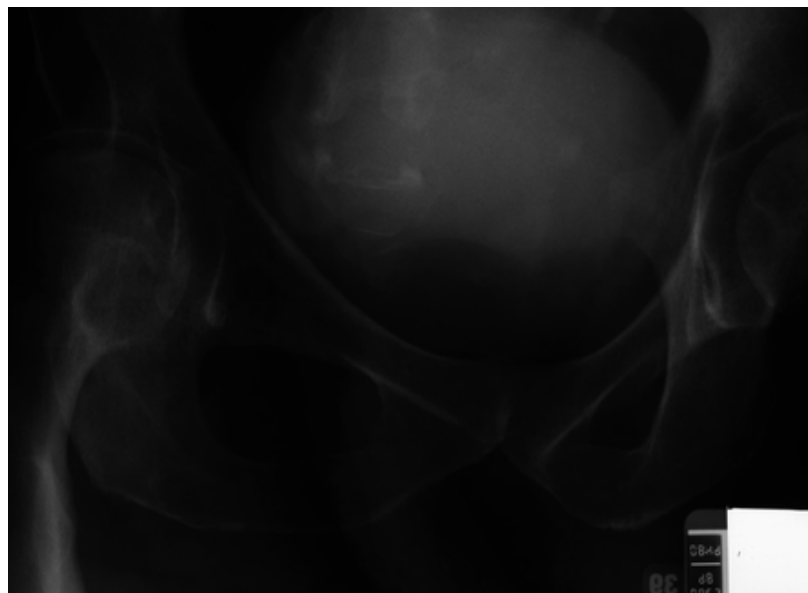
- $R_i(x, y)$  is dependent upon the size of the surround mask  $M(x, y)$  which is parametrized by  $\sigma$ .
- Different values of  $\sigma$  enhance different features of the input image: large values provide good spectral information, and small values provide good spatial information.
- So,

$$R_i(x, y) = \frac{1}{K} \sum_{k=0}^K \log \left( \frac{I_i(x, y)}{I_i(x, y) * M_k(x, y)} \right), i \in \{R, G, B\}$$

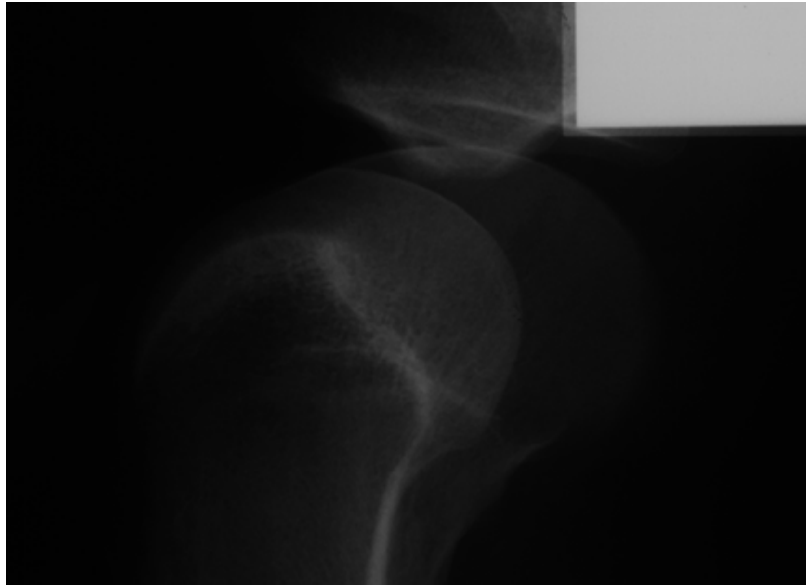
## Retinex—Examples

- Many digital medical images suffer from lack of contrast and sharpness.
- The Retinex automatically provides both enhanced contrast and sharpness.
- The following slides show the application of the Retinex image enhancement algorithm to
  - X-rays
  - Mammograms
  - CT scans
  - Other medical images

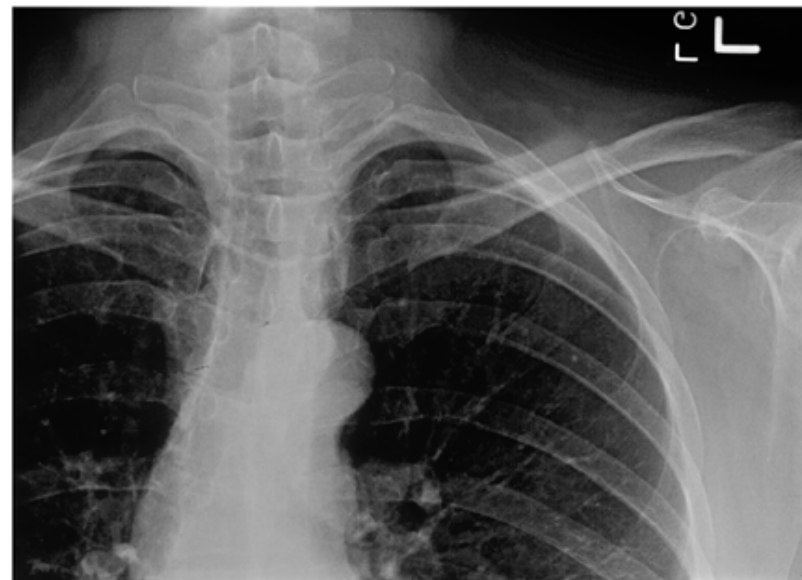
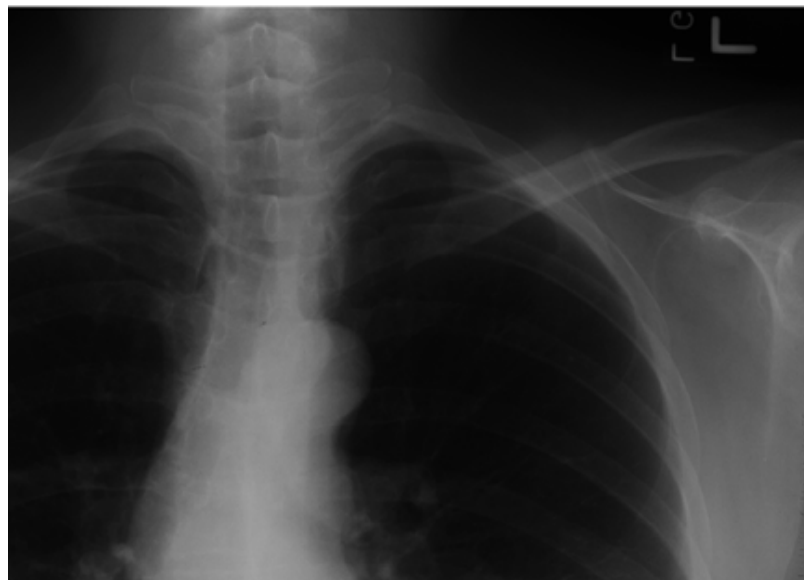
## Retinex—Examples—X-rays



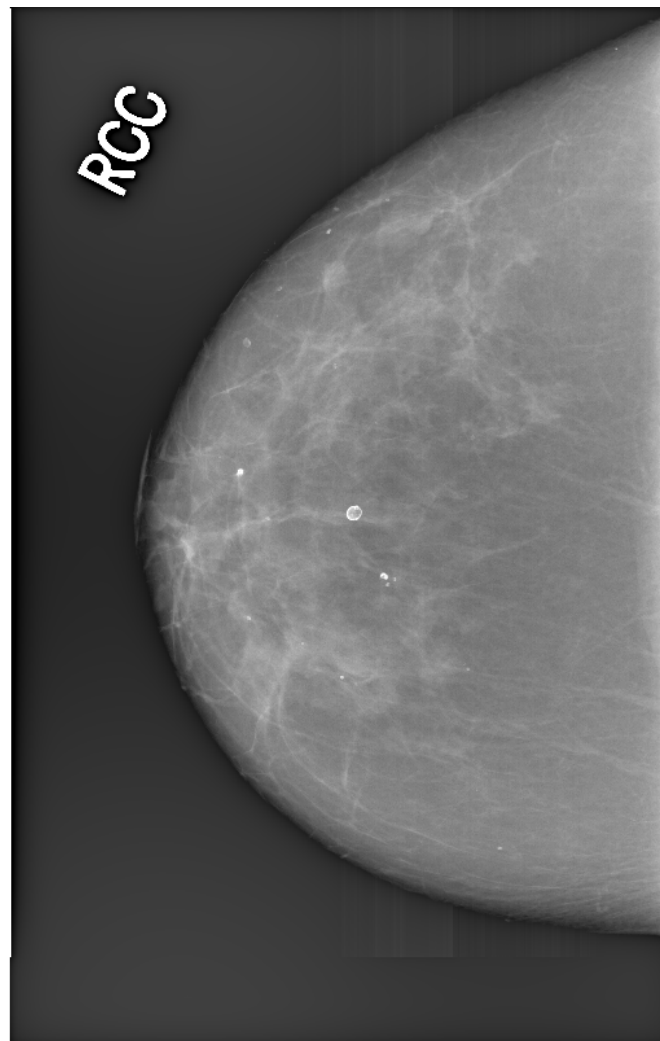
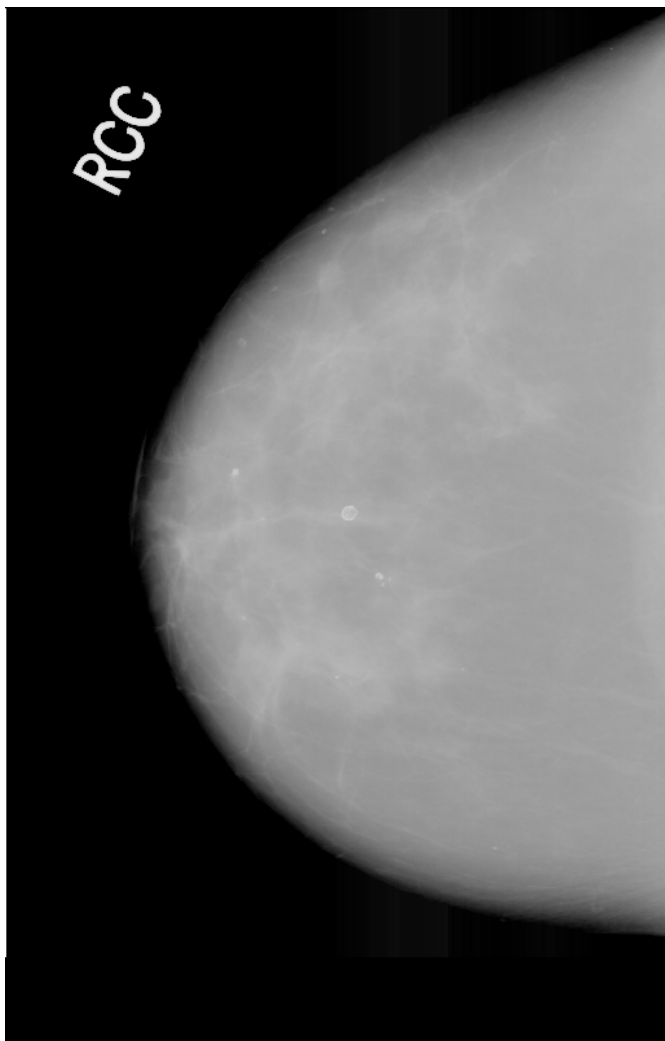
## Retinex—Examples—X-rays



## Retinex—Examples—X-rays

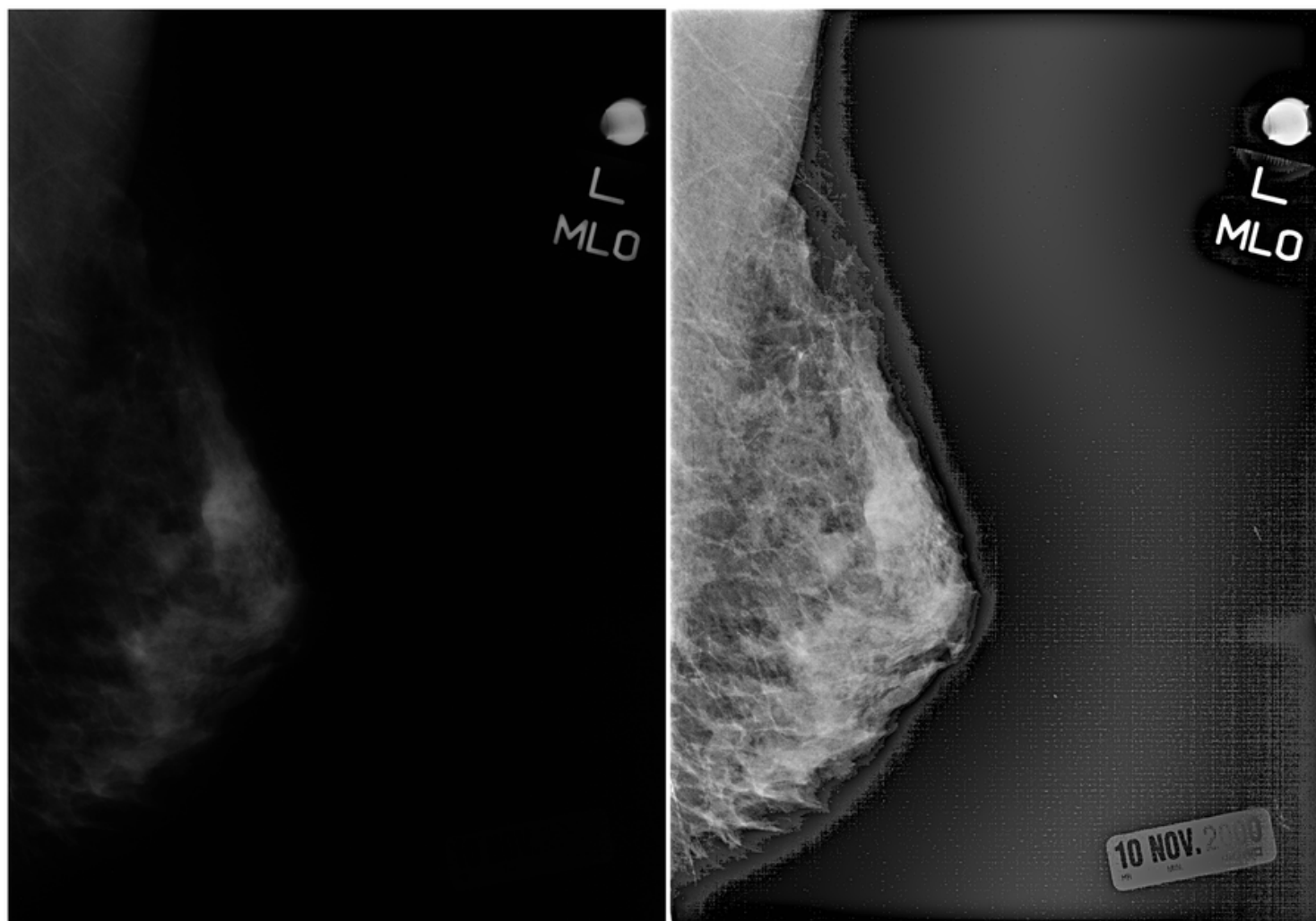


## Retinex—Examples—Mammograms

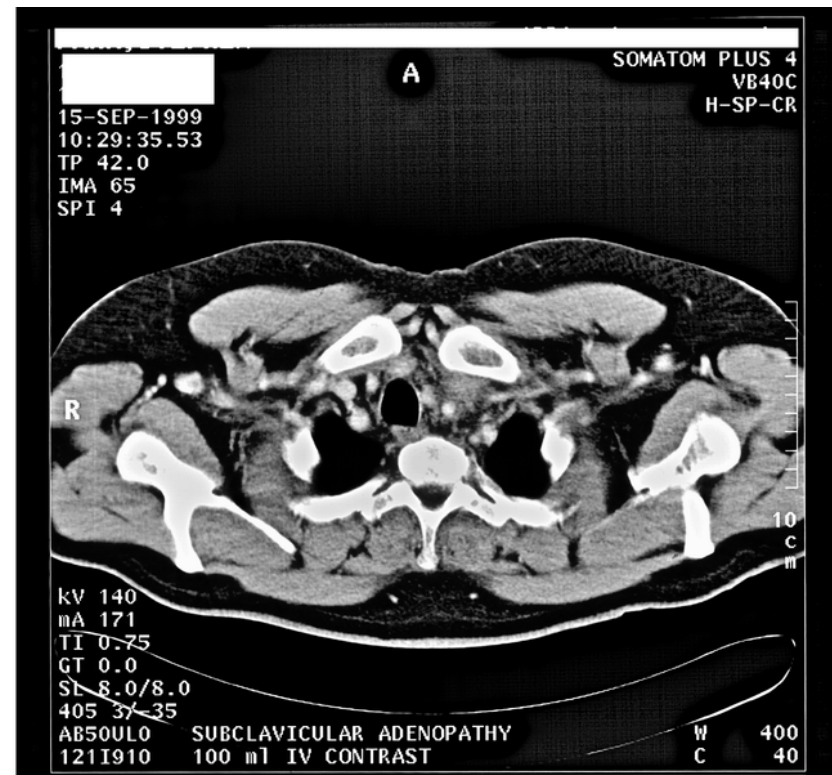




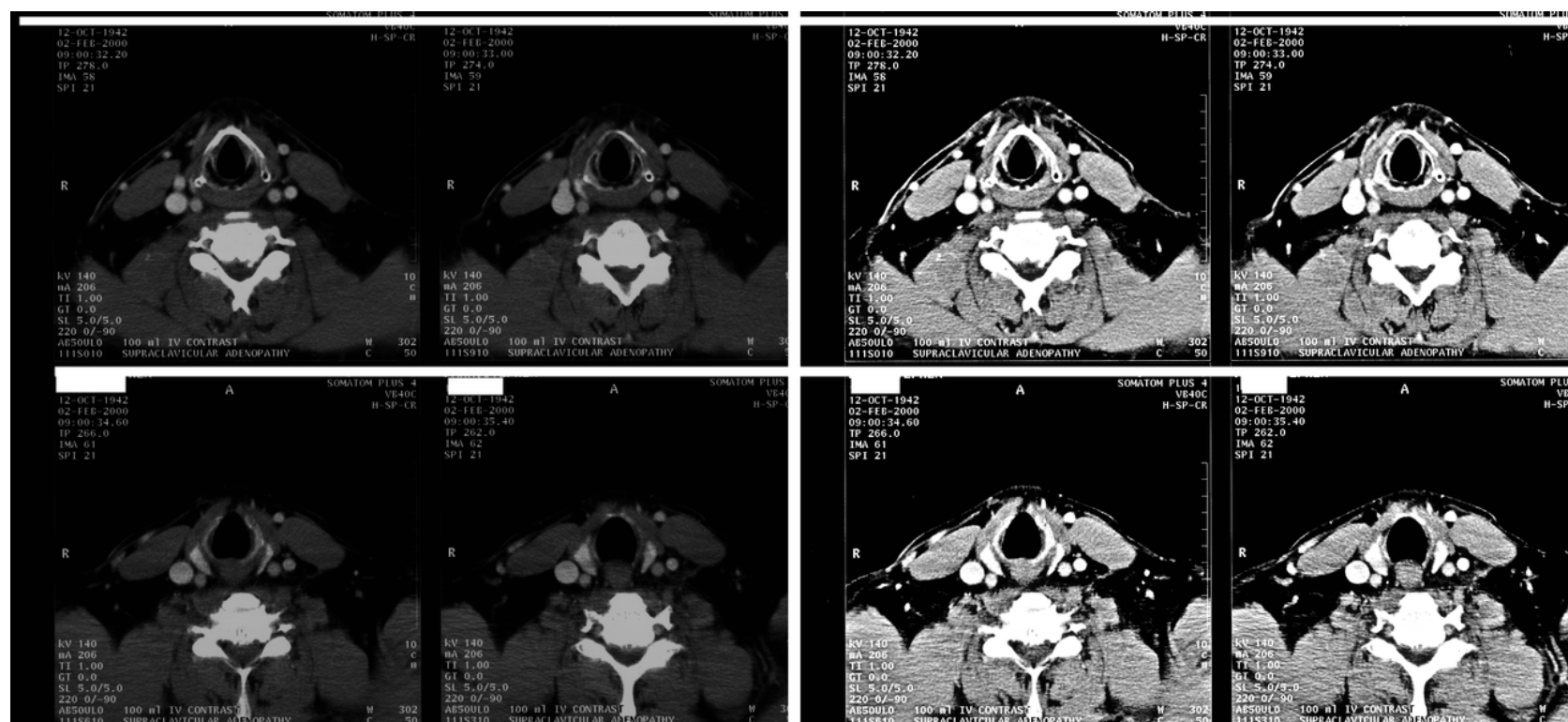
## Retinex—Examples—Mammograms



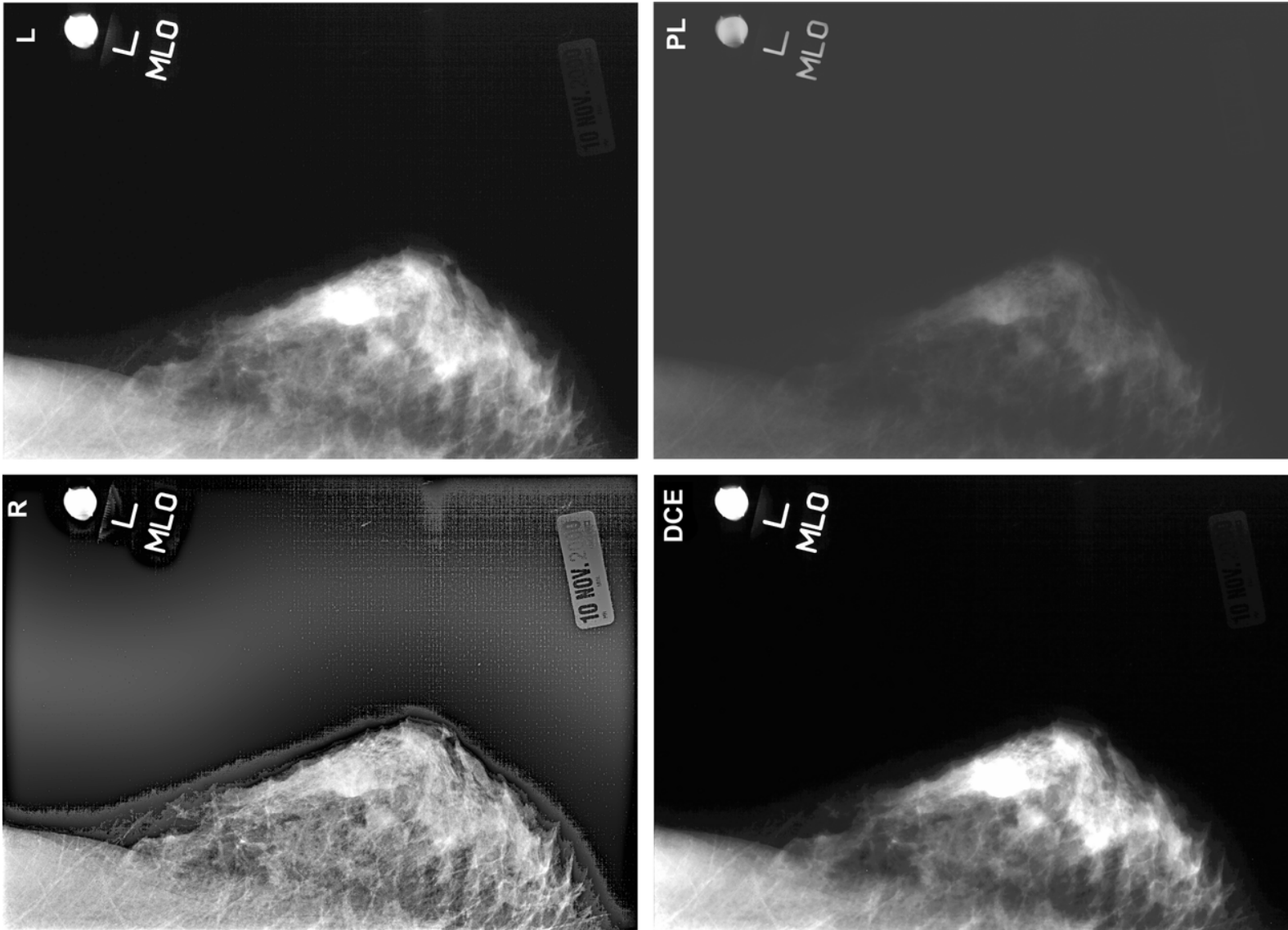
## Retinex—Examples—CT scans



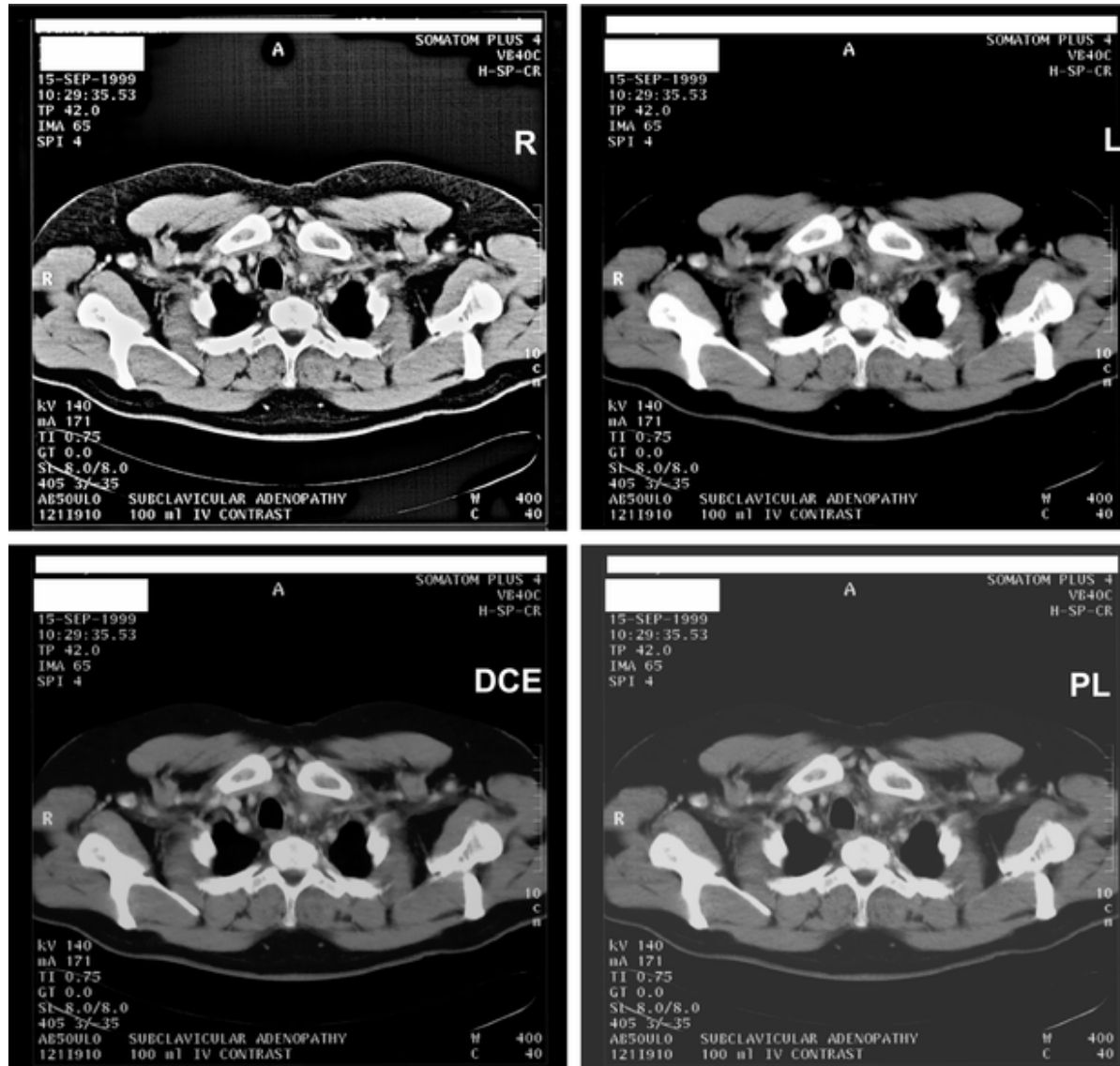
# Retinex—Examples—CT scans



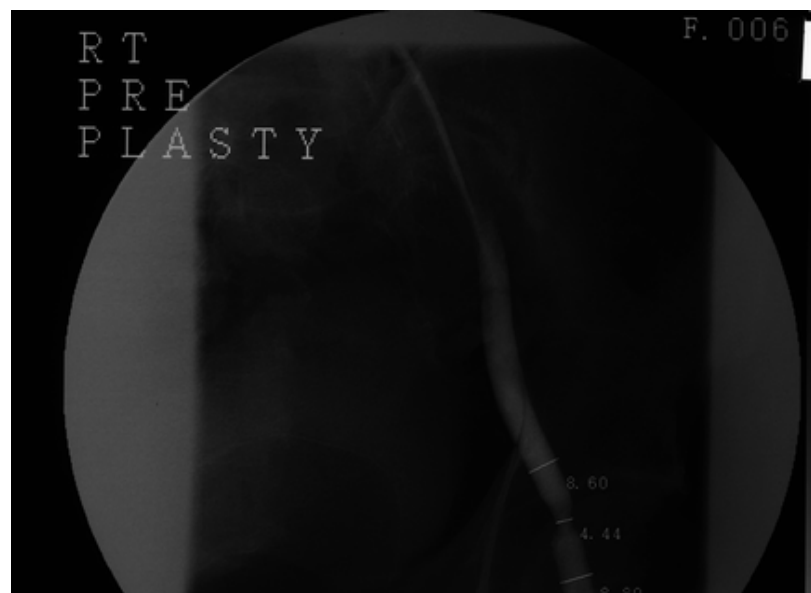
# Retinex—Examples—Comparisons



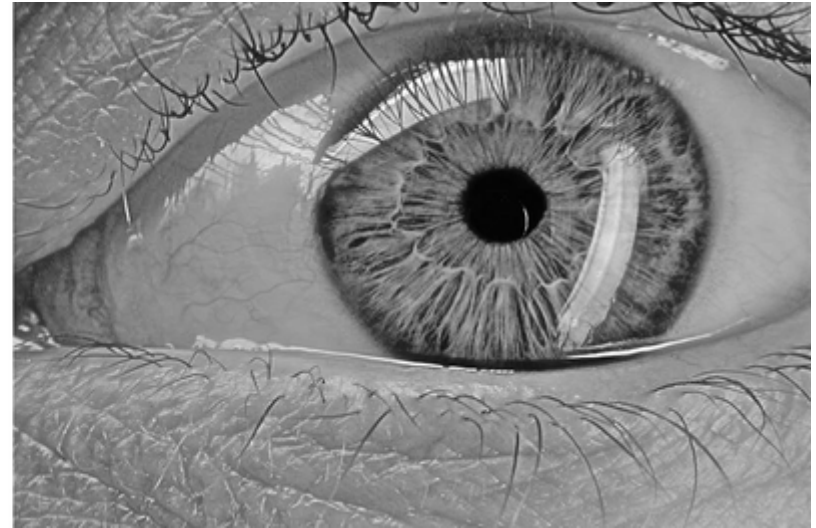
## Retinex—Examples—Comparisons



## Retinex—Examples—Other



## Retinex—Examples—Other





## Retinex—Examples—Other



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- **URL:** <http://dragon.larc.nasa.gov/retinex>